Final Report for NA-MIC Core 1a
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Interactive Segmentation

As part of our NA-MIC funded work, we have been developing an interactive segmentation scheme based on a statistical model of deformable contours to capture multiple anatomical features simultaneously. It is called the Robust Statistical Segmentor and is now a module in 3D Slicer [GAO_RSS]. The interactive method is started by the user drawing seeds in regions of interest in data. Local robust statistics are automatically computed for the features of interest, which are adaptively learned. from Once this is done, geometric active surfaces evolve based on energy minimization principles, and the interactions among the various evolving surfaces are constrained by the usual equations from Newtonian mechanics. This guarantees that the surfaces are mutually exclusive as well as removing the need that the union of the objects being captured should be the entire image domain. The balance of forces in conjunction with energy minimization and robust statistics guarantee that the active surfaces interact and converge to equilibrium at the desired positions of the given objects. Accordingly, this novel procedure naturally treats problems such as leakage and overlapping. The user has the ability to make any hand corrections after equilibrium is reached and so the method is fully interactive.. An example is provided in Figure 1 below.

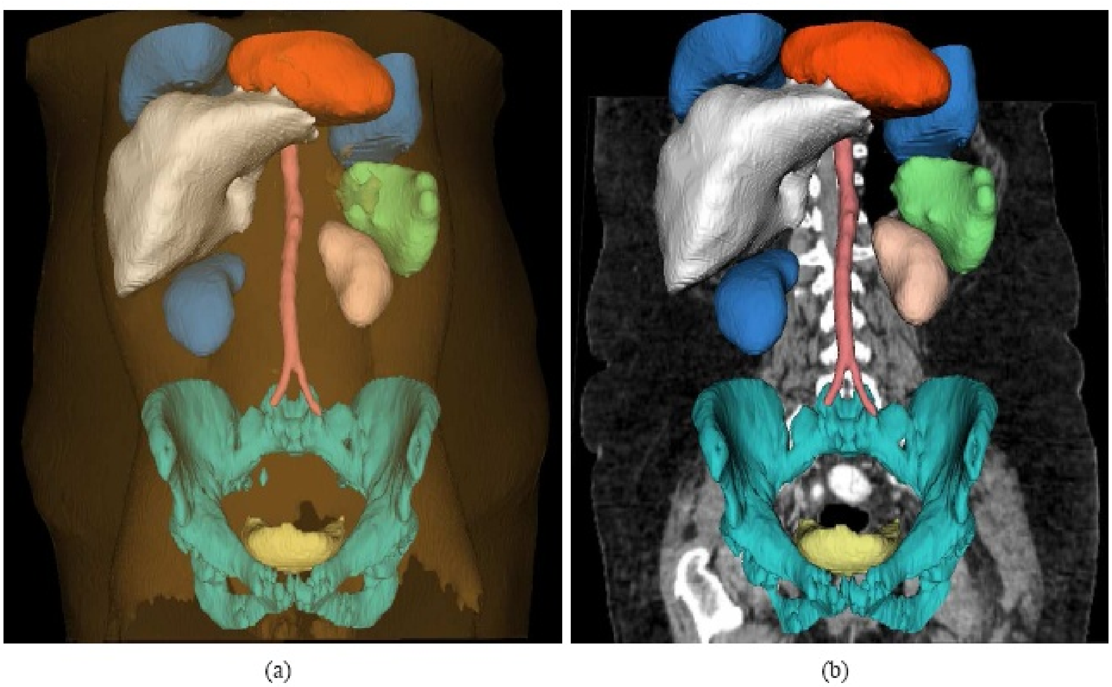

Figure 1. Segmentation of heart, two lungs, liver, two kidneys, spleen, abdominal aorta, pelvis, bladder, skin/muscle/fat. The subplot (b) removes skin/muscle/fat but overlays the original image.

Shape Priors and Multiscale Methods for Adaptive Radiotherapy

We have been working on using various shape priors as well as multiscale representation for shapes for the segmentation of certain key structures connected with radiation planning and adaptive radiotherapy [Kolesov,Gao_multiscale]. This consists of two elements: first we have developed a sequential method to estimate a shape prior using previously segmented structures as landmarks. It is based on probabilistic principal component analysis and probabilistic canonical correlation analysis. We derive equations in order to utilize these techniques for prediction. At a given stage in a sequence of segmentations, this approach predicts the most likely shape of the structure being segmented based solely on the segmentations of completed structures. Hence, the shape prior is independent of the image information around the target. This is applied to the problem of adaptive radiotherapy in oncology. Structures of interest in the head and neck region have insufficient image information and strictly image based approaches fail. Such cases also present major problems for methods that simultaneously perform segmentation and fitting of a shape model to image data. We have been also been employing a multiscale representation for shapes with arbitrary topology. Shape knowledge is many times incorporated by first constructing a shape space from training cases, and then constraining the segmentation process to be within the learned shape space. However, such an approach has certain limitations due to the number of variations in the learned shape space. Moreover, small scale shape variances are usually overwhelmed by those in the large scale. We have teated this problem by providing a multiscale shape representation using the wavelet transform. Consequently, the shape variances captured by the statistical learning step are also represented at various scales. In doing so, not only the number of shape variances is enlarged, but also the small scale changes are nicely captured. An example of the methodology is given in Figure 2 below.

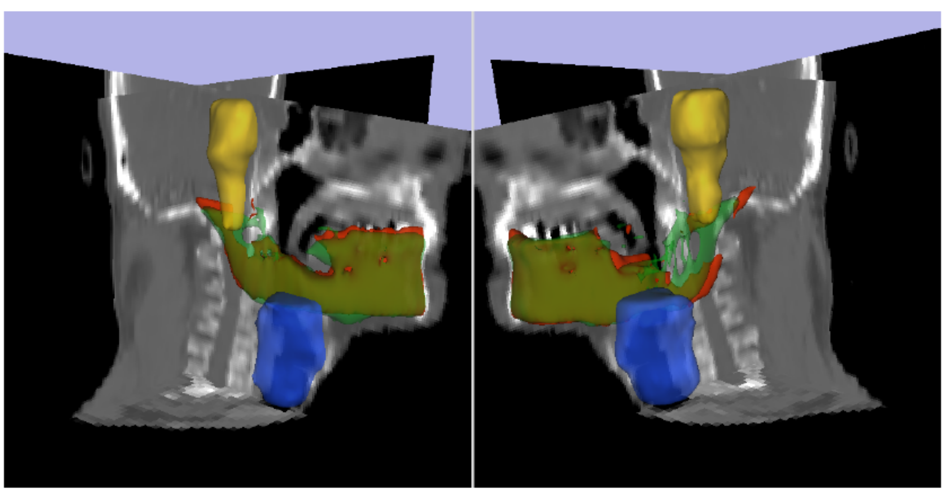

Figure 2. Two views of the 3D model are shown from CT data. Segmentations of the larynx in blue and the brain stem in yellow are shown; the ground truth for the

mandible's segmentation is in green. The predicted mandible, show in in red, is the shape prior computed by the approach proposed in [Kolesov].

Local/Global Active Contours for the Segmentation of Left Atrial Endocardium

We have been working on various methods to robustly segment the endocardial wall of the left atrium in delayed-enhancement magnetic resonance images (DE-MRI). We have found that the use of local-global active contours combined with coupled level sets as well as shape learning can lead to a very effective method for this challenging problem [Gao_atrium]. We give an example of the procedure below in Figure 3. Future work in this area will include the computer-aided statistical assessment of the enhanced regions in the DE-MRI which can greatly benefit the study of ablation therapy for atrial fibrillation patients.

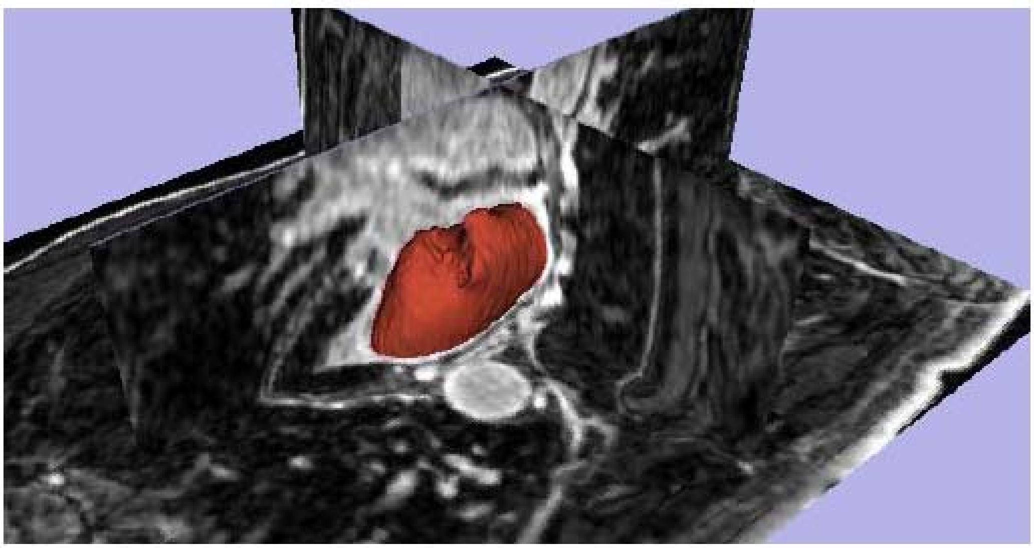

Figure 3. 3D view of the segmentation of the endocardial wall of the left atrium.

References

[Gao_RSS] Y. Gao, R. Kikinis, and A. Tannenbaum, "Interactive multi-object segmentation using local robust statistically driven active contours," submitted to *IEEE Trans. Medical Imaging*, 2011.

[Kolesov] I. Kolesov, V. Mohan, G. Sharp, and A. Tannenbaum, "Coupled segmentation for anatomical structures by combining shape and relational spatial information," *Proceedings of MTNS*, 2010.

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